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AUTHOR Leinhardt, Gaea
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ABSTRACT

This paper is designed to extend a dialogue on the nature of explanations to include instructional explanations. The paper explores the distinctions between specific types of explanations, (common, disciplinary, self, and instructional) with respect to specific features (problem type, initiation, evidence, form, and audience). Given this context three examples of instructional explanations are explored: one by a teacher in history, one by a student in history, and one by teachers and students together in mathematics. These three examples of instructional explanations are discussed and inspected with respect to the initiating condition for the explanation, the devices used in the explanation, and the rules for closure or evidence. Instructional explanations form a core part of all teaching whether or not the style is didactic or dialogue based. Knowing what the aspects of good explanations are, how these aspects are learned, and how to improve them is important for the education of teachers and for the general improvement of education. (Author/IAH)

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Towards Understanding Instructional Explanations

Gaea Leinhardt

Learning Research and Development Center
University of Pittsburgh
Pittsburgh, PA 15260

Technical Report No. CLIP-90-03
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Center for the Study of Learning

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Classroom Learning and Instruction Project (CLIP)

Technical Report Series

The Classroom Learning and Instruction Project (CLIP) reports consist of a series of technical reports describing a program of research at the Learning Research and Development Center, University of Pittsburgh. This research is supported by a number of private and public non-military agencies and is under the general direction of Gaea Leinhardt. The theme of the research included in this series is the relationship between teaching and learning in particular subject-matter areas such as mathematics and history. Some papers focus on teachers and how their understanding of specific content (e.g., graphing functions) impacts on their teaching; some papers focus on new assessment instruments that are attempting to measure the complexity of the interrelationship between content knowledge and pedagogy; others focus on the students and how their learning is influenced by their own prior knowledge in a content area and by the teacher's instruction. It is hoped that the cumulative findings of these studies will contribute to our understanding of learning and teaching. Particularly they will contribute to those aspects that are unique to particular topics and may in turn enrich our understanding of the field of teaching and learning as a whole. A list of CLIP reports appear at the end of this report.

Abstract

This paper is designed to extend a dialogue on the nature of explanations to include instructional explanations. The paper explores the distinctions between specific types of explanations (common, disciplinary, self, and instructional) with respect to specific features (problem type, initiation, evidence, form, and audience). Given this context three examples of instructional explanations are explored, one by a teacher in history, one by a student in history, and one by teachers and students together in mathematics.

Towards Understanding Instructional Explanations[1]

Explanations occur in response to some sense of query or demand. The form, location, and sense of the query help shape the explanation. Explanations, then, are a response to an explicit or implicit query. There are different kinds of explanations because there are different kinds of queries. Four different types of explanations can be distinguished: common explanations, disciplinary explanations, self explanations, and instructional explanations. All types share aspects with each other and with the rest of the world of discourse, but distinctions among these types of explanations are useful devices for analysis and exploration.

Common explanations occur in response to an overt question about how to do something or proceed with an event; they have a very local event/information-based flavor. Common explanations rest heavily on at least two speakers' sense of how such questions are to be asked and answered. (How do I re-light the pilot light in my instantaneous water heater? Why are the registration forms due now? Why does this journal have these special submission requirements?) The query is focused, short, and the asker usually is quite certain that the explainer can answer the question. (This includes queries for locating the right person to ask, e.g., Who do I ask how to find the chambers of Judge Thompson?) These are common because they are a frequent, vital part of our everyday life, especially when we enter some aspect that is not common to us as an individual. These queries and answers are also notable because of their lack of connection or grounding in subject matter, their brevity (one to four exchanges are usually sufficient) and lack of intimacy, and their lack of a deep sense of inquiry on the part of the asker. They are also notable for their reliance on a sharing of the social setting and rather surface features of cultural exchange.

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Disciplinary explanations, on the other hand, arise from a totally different sense of query. These explanations arise from queries that may be either overtly expressed, or as yet unrecognized as queries, they exist across large distances of time and place. The form of such explanations is somewhat formal and ritualized to maximize the communications, given the absence of face and voice. Disciplinary explanations are built around a core of conventions that help to determine completeness and include features such as what are the important questions, what constitutes evidence, what may be assumed, and what the agenda is for the discipline. These explanations have rules that help the community of thinkers in that field focus on the task of constructing new knowledge and reformulating extant knowledge. In one sense these are highly social events -- they are specifically to be shared and are dressed up for the occasion, so to speak. They are also social because explanations for one group are not particularly recognizable, let alone acceptable, to another--a physics explanation is quite different than one in history or literary criticism. (The attempt to make them similar is documented in the writing of Hempel [Hempel & Oppenheim, 1948, 1988] [Collingwood, 1946].) Disciplinary explanations contain a sense of justification within the bounds of shared rules. In another sense these explanations are non-social, because the presence of a physical audience is not a requirement. From an educational standpoint it can be argued that one goal for students is to begin to approximate these disciplinary explanations in their own discussions within that subject. Disciplinary explanations do not provide practical information in the sense of the everyday but they do provide "real" information in a real form, in the sense of valued by that particular community.

Disciplinary explanations serve the function of proving the legitimacy of new knowledge, reinterpretations of old knowledge, or challenges and answers to existing knowledge. These explanations are carried out with a legitimacy sanctioned by the particular discipline. The formalisms of mathematics tightly constrain explanations; however, new computer technologies have changed the form and content of new mathematical knowledge and its intendant explanations. In mathematics classrooms, mini-disciplinary explanations -- which may occur in the form of expansions, incorporating known truths, generating alternative representations with

compatible solutions -- contribute to informal explanations of the discipline. In history it is more problematic, as Hallden (1986) says,

> There exists no such common and uniform view of history. Jurd (1978b) states that the subject of history has an 'open structure', as opposed to scientific subjects and mathematics which have a 'closed structure'. Descriptions and explanations in history are subject to transformations in quite a different manner than is the case with the scientific disciplines. Furthermore, in history it is not easy to delimit an area for investigation, or to define relevant variables and their functions in explanations" (p. 56).

Although the inductive explanations of mathematics and science are now more frequently discussed, interpretation of the meaning of the stance of the explainer is not in the forefront of the disciplinary discussion. In history and in most of the humanities, disciplinary explanations most often contain this double layering, as Collingwood (1946) and von Wright (1971) refer to it. The fact, the interpretation, and the stance of the interpreter are all elements in the explanational web. (See also the collection of essays on explanation edited by Manninen & Tuomela, 1976).

Self explanations, as the name suggests, are explanations given to the self to clarify meaning or to incorporate new knowledge with old. The self may be a group that is facing a shared task; but more commonly the self explanation is intra-individual. Its verbal trace is highly idiosyncratic and fragmentary, leaving unsaid the known bits of information and stopping when the end is in view rather than when it is actually arrived at. The query is a sense of incongruity or desire for generative cohesion. The query may in fact be as ill-formed as the answer. In distinction to the common explanation and to the disciplinary one, the time frame for self explanations is longer than the first and usually shorter than the second, the topic is rarely how to get through an event. Self explanations are a large part of learning and engaging with complex material. The sense of asking and answering ones' own questions is perhaps the most powerful

indicator of meaningful learning behaviors as contrasted with so-called mechanical or rote learning.

In younger students this sense of self-explanation inquiry has been directly taught, and when the inquiry matches the eventual demands of the situation the instruction has been very fruitful and facilitating (Palinscar & Brown, 1984). In slightly older children (12-14) such inquiry and explanation is often an indicator of academic success, although it is a feature of learning that researchers want to see more often than they actually do (Leinhardt & Putnam, 1987; Peterson, Swing, Braverman, & Buss, 1982). At the high school level, when dealing with complex material, the form and intent of such inquiry while studying is a powerful predictor of knowledge acquisition (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). As Chi and her colleagues state in reference to self explanations, it is "the students' contribution to learning." (Chi, et al., p. 146)

Instructional explanations are the teachers' and texts' contributions to learning and these explanations are designed specifically for communication of a particular aspect of subject matter knowledge they are designed to teach. However, they teach in two distinct ways. First, instructional explanations convey, convince, and demonstrate; and second, instructional explanations model explaining in the discipline and self inquiry. Such explanations occur in response to an actual query, an anticipated or probable query, or perceived puzzlement. Instructional explanations are designed to explain concepts, procedures, events, ideas, and classes of problems in order to help students understand, learn, and use information in flexible ways. They are complete with respect to their verbal trace, but their form is not as ritualized as it is in a disciplinary explanation. They are decidedly social (computers notwithstanding) and local in time and place. Instructional explanations tend to be elaborate and reflect both the rules of communication and the rules of the discipline. Thus, they make use of examples from both the personal, shared experiences of the community of learners and from the discipline itself. They can draw on representations that are colloquial and familiar and on abstract or intermediate representations (for the idea of intermediate representations, see White, in press).

Instructional explanations in mathematics, history, and most recently writing, have been the focus of an ongoing program of research. Work on instructional explanations in mathematics has developed to the point of a testable model of such explanations (Leinhardt, 1989), and includes a system of goals and actions. This model connects with research on the importance and functions of external representations and their role in reasoning (Gentner, 1983). The work in history is relatively recent and has emphasized analyses of the nature of what gets explained (Leinhardt, 1990; Leinhardt & Odoroff, 1989). The work on writing has focused on the utility of constraints in explanations which serve as guides and connect with research on constraints (Odoroff & Leinhardt, 1990; Simon, 1980). The object of the research is an integrated discussion of instructional explanations.

The model of instructional explanations in mathematics is successful in differentiating between novice and expert teachers. The model also captures explanations of teachers across a wide range of instructional levels, from those who are teaching mathematics at the second grade all the way up to those teaching college courses.[2] The model for explanations in mathematics instruction suggests that in order for an explanation to explain, several conditions must be met. The subskills necessary to follow the explanation must be in place--for example, although it is easy to show algebraically why a two-digit number times a two-digit number requires the cross product terms, using algebra is not an appropriate way to explain this to fourth graders. Any devices used in an explanation, such as representations or micro-worlds, must be known and the operations in that space be accessible, before using the device to explain something else. For example, a set of paper strips, which might be used for explaining fractions but which require uniformity of length and alignment to operate "correctly," cannot be introduced as a new representation at the same time as they are being used to explain something in the symbolic system. Other features of the explanation model in mathematics instruction include identification of the problem; completing all

[2] It has not yet been rigorously tested against the type of shared, public explanations in which both students and teachers together construct meaning; however, in informal investigations it seems to hold up fairly well.

parts of the explanation, verbal and representational; demonstrating the principled legitimacy of the solution; and identifying circumstances of use and misuse (Leinhardt, 1989).

Disciplinary explanations are a part of teaching and learning because of the role they play in establishing "real questions" (Lampert, 1989) and in guiding rules of evidence and justification. For some, disciplinary explanations are the ultimate object and vision of subject matter based instruction. Self explanations are the processes of developing meaning for the self and as such are also a vital part of learning (Chi, et al., 1989). Instructional explanations build from their particular contexts both physically and socially; they tend to have redundancy as a conspicuous feature. The good teacher strives in the explanation for vividness and distinction from the surrounding mass of information. Disciplinary explanations are admired, on the other hand, for their elegancy and parsimony.

Insert Figure 1 here

A summary of some of the distinctions among these three types of explanations is presented in Figure 1. What is suggested by this figure is that part of the differences among the explanations consist of differences in what gets explained, how an explanation is initiated, what constitutes rules of evidence and legitimate authority, when an explanation is complete, and the audience for an explanation. To review, what gets explained in a disciplinary explanation is an answer to an extant question or a reformulation of a position in light of a disciplinary dialogue. The explanation is initiated by a public challenge or as an act of completion to a previously incomplete understanding. What gets explained when one is explaining to one self in a learning setting is how to work around a problem, how to connect a new piece of information to existing information, or how to restructure or rearrange existing information. This type of explanation is initiated when an incongruity is noted or an integration needed. In instructional explanations what gets explained beyond what is presented is material not understood, or material which may not be understood or which may have future value not immediately evident. It is initiated in response to

overt or covert queries or when a piece of information has been flagged by a teacher as important. (N.B., instructional explanations may be given by teachers, students, or both together).

The rules of evidence for discipline-based explanations are ritualized and shared, and the form tends to be formal, almost coded (especially in spoken presentations), striving towards parsimony and elegance. Completeness is required especially in the written forms. In contrast, the rules of evidence for explanations for self are either completely unrestricted, including folklore, personal experience, or overly rule-bound (the former is often the case for students studying psychology texts, the latter for students studying physics or algebra). The verbal trace of self explanations as reported by Chi, et al. (1989) is fragmented, idiosyncratic, brief, and sometimes redundant. Instructional explanations use the discipline-based rules of evidence, shared personal experiences, and texts. Richer uses of external representations and analogies are also in evidence. Such explanations are complete when understanding is observed and claimed. This leads to redundancy in the form and an informality of presentation, which is usually spoken.

Issues of audience are straightforward. For disciplinary explanations, the audience may be present or absent and large distances of time and space are common. The audience consists of other members of the community of the discipline and other amateurs; the discussions are most commonly and ideally open and public to those who can follow them. The audience for a self explanation is the self. For instructional explanations, the audience is usually physically present and consists of teachers and students. (As computers and television play larger roles in teaching, this local, intimate aspect will no doubt change.)

This discussion has avoided engaging in more than a passing reference to the intense philosophical debate surrounding "explanation." The 1971 volume by Georg Henrik von Wright, *Explanation and Understanding*, and the 1988 volume edited by Joseph Pitt, *Theories of Explanation*, capture many of the critical moments in the debate over the last 45 years. The avoidance of the debate here has been due to three issues: first, the debate has centered out a layer from the issues of interest here, namely, a debate about the science of knowing science;

second, the level of analysis is too fine-grained to be helpful currently to the coarser-grained problem of instructional explanations; third, the debate has focussed on "What counts as an explanation." The debate strategy for defining or generating explanations of explanations has been a winnowing one. However, the strategy pursued here is closer to those of archeology: cast a net in an environment of explanations and work with those captured phenomena; if some elements are judged to be inappropriately included, that is probably less harmful than never getting started on the enterprise at all. With these caveats the discussion continues.

Given this family of explanations, what kinds of questions do we ask? Why are we explaining explanations? For instructional purposes what are the components of a good explanation, where good means that the explanation has helped to expand understanding? What are the similarities and differences across different subject matter domains? Is it even worth pursuing the notion of a "good" explanation in math and history? What are the devices or tools that are used in explanations and how are they used?

To begin to investigate the nature and form of instructional explanations we have been building a data base of instructional episodes across a wide range of grades, second grade through college, and a wide range of subjects -- mathematics, history, geography, writing, and psychology. We have focussed on some specific aspects of these teaching episodes to begin to learn what types of things get explained in different circumstances and what the major devices are for constructing explanations.

In this paper three examples of instructional explanations are discussed and inspected with respect to the initiating condition for the explanation, the devices used in the explanation, and the rules for closure or evidence. The first two explanations are drawn from an American history class, one is from a teacher (Ms. Sterling) and one is from a student (Paul). The explanations are both in the blocked form, that is, self contained. The first is by the teacher and deals with a theme in the course, liberty and power; the second is by a student and deals with an event, Reconstruction, related to the theme. The third explanation is in the form of a group dialogue in the midst of a mathematics class. The students and the teacher together build an

explanation to justify a particular calculation. These three examples are chosen to show aspects of explanations: what stimulates them, how is evidence used and what kind of evidence, when is the explanation over or completed? The student episode demonstrates the process of students' learning how to develop explanations that are both valid with respect to the discipline and valid with respect to the conventions of communications among their classmates. The teacher explanation shows the modeling of an explanation.

During the 1988-1989 school year we observed every class in the first semester in one AP history classroom and audio or video taped all of the classes from October through January. The following fall (1989) we audiotaped the first three and a half weeks of school to overlap with the first years' observation. The students were high school juniors. All of the lessons were transcribed. We are now in the process of analyzing those lessons.

In examining the history lessons we came to realize that different forms of explanations, blocked or self-contained and ikat or distributed, existed for different types of historical situations (metastructural, events, structures, and themes). These forms have been discussed in depth elsewhere (Leinhardt, 1990). One type of explanation combines historical themes with specific events. In history, events form the story structure of what happens, but this is only one aspect of history. Basic societal structures such as the economic and religious systems impinge upon the events and are themselves transformed by events. Issues such as power, political compromise, or agrarian and mercantile tensions stretch over time and place. These issues become organizing themes which weave together specifics. Both texts and teachers explain not only the happenings but these larger more complex units of structures and themes. Students need to learn how to explain these bigger chunks as well, and there is evidence to support the idea that students do over time acquire the capability of offering more coherent and acceptable explanations (Leinhardt, 1990). The first two examples that follow are drawn from this data base and are brief (not a normal property of historical explanations). The examples come from the first month (early October) and the third month (early December) of school respectively.

In the first example, which is a rather lengthy explanation, the teacher is layering an explanation over several days. The explanation dealt with the question: "Did the Founding Fathers make a good adjustment between liberty and power when they wrote the Constitution?" The deeper question was, "Why is the Constitution as it is, and how did it become so?" The theme of liberty and power was one that floated in and out of the course throughout the year. Sterling started this part of the explanation with the embedded question of what were the weaknesses (power weaknesses) in the Articles of Confederation that lead to the Constitutional Convention, or restated, what was the imbalance in power? The answer that she constructed with brief help from the students was that the Articles gave sovereignty to the states, thus dividing power; there was no overarching judicial structure, leaving a power vacuum; and there was no centralized power of taxation, producing economic powerlessness. This answer set up the expectation that the 'new' government would repair these. The second embedded query was "on what did the delegates agree?" The answer was popular sovereignty (a shift in power) and a stronger national government, one that presumably could tax and had a judiciary (a new power). On the way there was a definition of liberty and power and a flagging of this relationship as a theme for the course.

Insert Figure 2 here

Figure 2 presents a net of the central ideas in this explanation of the formation of the Constitution in terms of the failures of the Articles and the agreed-upon premises for the reforms. A query about power and liberty starts the discussion. The failure of power structures is shown on the left and the role of agreements to restructure these power arrangements is shown on the right. The sense of an aside or interruption is shown (on the lower right of the figure) by the extended, if necessary, aside on power and liberty. What was accomplished in the explanation was a modeling of question form and the summoning of evidence to begin an explanation. What was also shown is how one question leads to the next. Clearly, after one has finished saying that

the framers of the Constitution all agreed on some points, one will move to what they disagreed on.

In this segment two metastructural tools were used, namely analyzing the economic and political causes and consequences surrounding an event. The failure in the Articles to provide a solid unified tax policy (along with currency, banking and other economic issues) coupled with the location of sovereignty in the states, were major weaknesses. The discussion of agreement among the delegates was a prelude to an entire thematic unit on compromise, political compromise and its successes in the case of the Constitution and its failure in the case of the Civil War.

Insert Figure 3 here

Figure 3 gives the entire text of the explanation; the segments that are deleted are brief one-line exchanges or redundancies[3]. The explanation started as a query to students, but the initial attempts by students to respond were not full enough and so the teacher "took over" to show what a complete answer would look like. There was a short answer flavor to the early part of the discussion: three areas of weakness, a few areas of agreement. However, these were continuously reattached to the initial issue of the Founding Fathers to emphasize this point. Midway through, she called for a definition of liberty and power.

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[3]The protocols displayed here use a number of transcription conventions. First, the text is presented exactly as spoken; second, inaudible words are indicated by a pair of square brackets containing two dashes; third, where words represent a transcriptionist's and multiple listeners' best but uncertain gues they are enclosed in square brackets; fourth, where a speaker stops in mid-word, the sounded letters of that word are shown, followed by an underscore mark to indicate part of the word is missing; fifth, whei portions of a protocol transcript have been omitted in a figure, that omission is indicated by a three-dot ellipses (. . .), a blank line between sections, and a noticeable skip in line numbers; sixth, the line number indicated in the left margin are numbers assigned by the word-processing program and have no special meaning other than an indication of length of the protocol, although they are used as identifiers for specif lines in a transcript and as aids in counting numbers of lines of talk associated with various speakers.

In the early part of the explanation, when she was trying to support the students' attempts, she used a switch in voice from third to first person (from "What were these three weaknesses?" to "We'd better do something about this document. And in fact we met at ...") This device helped to reposition the students in both the question space (Why could we have wanted to change the document) and the answer space (it will flow out of known problems we have been talking about). This latter hint may well connect the student to information already existing but existing in an inert way. Later on in the explanation, she did this again, after she asked for areas of agreement: "Everybody [third person probably], all fifty-five of us [first person] who are in the session in Philadelphia are going to say, 'Yes, Pete, that's a great idea. That's what we want in government'." This is an analogical device of sorts. It flags the parts of the past that are accessible from personal knowledge. The danger in this is that it can be misapplied and one can get lost in the analogical space (is it us now, or us then?) and mismap as well (Gentner, 1983; Gick & Holyoak, 1980, 1983; Holland, Holyoak, Nisbett, & Thagard, 1986).

A second device that was used in the explanation, which served as a warning that she was going to make an aside or move on, was summarizing. Sterling summarized several times: "This is what is wrong;" "these were areas of agreement." This was both a reasonable pedagogical move and a reasonable discipline-based move. In essence, the teacher was reiterating what had been accomplished over the course of the discussion to flag a move to a new idea or an elaboration. After the discussion on power and liberty, she returned to the initial subquestion of areas of agreement for a point about separation of powers. Two explanations were, thus, left 'unfinished'; the areas of agreement needed to continue with areas of disagreement and the form and content of the final document. Second, the subtle point about power suggested that the delegates did not have the power to write a new constitution as such power was with the states, so they had to develop a circuitous self-justification and ratification process.

The issue of audience is particularly interesting in this lesson. The audience for the teacher and the speaking students was the rest of the class. However, the audience was also an invisible examining board. This was an AP class, which meant students were learning new

material, new forms of discussion and presentation, and acceptable forms of answers to classes of questions for an examination. The exam was ever present, but rarely spoken about. In this sense, the teacher was acting as coach in preparing students to assemble historical information in support of a position in a particular context.

In the second segment, a lengthy protocol from a student who was learning how to build and express an explanation is presented. He made tremendous progress from the beginning of the year when his back references were always to "teacher said," and his average utterance was only a couple of lines long. In this explanation he was trying to show how the period after the Civil War could be considered a constructive one in spite of the many negative features. He was in an extended dialogue with other students. Figure 4 displays the map of his explanation.

Insert Figure 4 here

The underlying query which produced this explanation dealt with the political consequences of Reconstruction and perceptions of those conditions after the Civil War. ("We are going to question whether the period was a constructive one, whether it was a destructive one." Sterling, 12/6/88, lines 52-54). The class was having an open discussion on Reconstruction and Paul explained why Reconstruction was both constructive and necessary. He started in the early part of the class with a brief but fairly complete discussion of the integration of Black Americans into society. He used a fundamentally structural explanation as opposed to events (this happened, then this) or thematic (shift in economic power base). As the net of concepts shows in Figure 4, he touched on the economic (Freedman's Bureau), social (free education), and political (voting amendments) aspects of the redefinition of Southern Blacks' role in American society. He concluded the first part by asserting Reconstruction was constructive, in a sense a summary. In the second part of his explanation, he backed up and considered the entire situation following the Civil War. He focused on political disintegration, and offered the presence of factions as evidence of disintegration. The political groups in the country were

portrayed as responses to these social/political problems. Paul stated that the radical position was necessary given the times and was positive in spite of the graft and failings. He referred back to his initial statement and concluded that it was a constructive period.

Insert Figure 5 here

Figure 5 shows the complete protocol of Paul's discussion. The initiation was clearly the teachers' earlier query. He had a strong command of facts, which he used as his evidence. There was no particular appeal to authority other than these facts. (He might have referred to specific authors and their positions, such as Hofstadter or Beard, something often done in the class). He made an interesting interconnection with another student --"As Eva said" -- and then added to her statement. Later he said, "Like Arnold said." His use of voice "we" was inclusive of the other speakers and part of the form of discourse as in, 'we find.' In form, this is an instructional explanation because in its spoken, and its loosely, redundantly constructed form, it is designed to inform the rest of the class. However, with tightening and more precise use of facts and language it would move more closely into the space of a disciplinary explanation. Paul's use of language was occasionally awkward especially when he made connections between ideas (in addition to this, now, that is why I would say that) that tended to mask the structure of his explanation. This gave the explanation a list-like flavor even though the list was support for the answer and even though there was a concluding sentence. The invisible audience of the examining board was noticeable; the statement and restatement of his conclusion seemed spoken to an examining board, not only to his classmates.

History classes at this level have a different character and objective than mathematics classes. Nonetheless, mathematics classes also have explanations which are initiated, make use of devices, and conclude. These explanations are designed to teach and move students towards the understanding of a discipline (Lampert, 1990). They accomplish this move towards understanding by invoking instantiations of principles, the use of representations, and the clear

demarcation of problems. The next segment comes from a small section of one 5th grade class taught by Magdelene Lampert during 1988. This class was the first in a series of ten classes during which the main focus was on functions and graphs. All ten classes were video taped and transcribed. In addition, pre- and post-interviews were conducted with Lampert and observational logs were kept. In the first class the focus was on the knowledge students had of grids and graphs. Lampert planned to move into that discussion from a quick discussion of mapping rules. The first "problem" was to find the function rule, use it, but not state it. After working through 14 ordered pairs on two charts with the same rule ($y = 3x + 1$), Lampert gave 1/4 as the input number. A discussion about fractions, then referents and operations ensued. Figure 6 diagrams the resulting discussion.

Insert Figure 6 here

A student answered that if the input was 1/4 the output was 1 and 3/4. Lampert asked why and the student responded, "Because 1/4 times 3 is 3/4, and then add one." Lampert again asked why ("Who can explain why one fourth times three is three fourths?"), but this time in reference to why 3 x 1/4 is 3/4.

Another student gave an answer which was ambiguous, namely, that if you had one piece of pie and someone brought two more you would have three pieces "that come out of four pieces of pie." (This appeared to be additive rather than multiplicative.) After a discussion of equal sizes, a third student challenged the first answer of 1 and 3/4 and claimed that one whole would also be correct. This third student's reasoning was that one fourth is one piece of pie, times three, that would be three pieces, and then you should add one more piece, which would make a whole. What is particularly interesting is that the last two answers were both unclear, but the second one was explained in enough detail by the student so that the confusion could be detected and discussed. The "mistake" was shifting the unit of whole pie to one piece of pie during calculation, but then reclaiming it in the answer of four fourths. In fact, the child drew a picture of a whole pie

divided into fourths and pointed at one segment, showing one piece of a pie. This drawing introduced a representation of the problem for the class. The teacher put x's in three of the student's four pie pieces and asked for a label. The student chose three fourths as opposed to three pieces of pie. Then the teacher said, "Plus one whole," while the student simultaneously said, "Four fourths." The student added the pictorial pieces and got seven fourths, but the picture was also of one whole and three fourths, which formed the link to the first answer. This then ended this particular part of the explanation.

The explanation continued with why 3/4 plus 4/4 is or is not 7/4. The jointly constructed explanation got to the heart of the slipping unit problem evidenced by the second and third students. The explanation closed when all of the representations were shown to be consistent with each other. The initiating condition for this mini-explanation was a task in justifying a calculation, and the explanation continued with statements of procedures that were believed by all of the students. When a part was reached that was not shared a second explanation was offered. The explanation made use of a representation offered by a student, in this case a pie. Finally, the original answer and the pie answers were reconciled and the two symbolic forms were shown to be equivalent through the representation. The disciplinary rules were supported in that two systems were shown to support, not contradict each other.

These mathematics students were much younger and their language was not nearly as sophisticated as that of Paul, but they made use of devices such as physical representations, absent in historical explanations, with great smoothness. They also showed some facility with both additive and causal connections. "**Because** one fourth times three is three fourths and then you just add, add a one." Later, "**Cause** three fourths plus four fourths equals seven fourths." A good deal of the causal part of the explanation was in fact carried by the drawing and correct marking of the pictures in addition to the language. Because Lampert was a part of the dialogue there was considerable support (in the sense of scaffolding) for both forming appropriate supporting reasons and for using causal language to express them.

The mathematical explanation is instructional in several ways. At the most global level it is a layered discussion on a single function rule ($y=3x+1$) where the repeated use of the rule is demonstrated by mapping "inputs" to "outputs." This global explanation is entirely in the hands of the teacher in much the same way that the choice of question for the Constitution was in the hands of Sterling. At a more focussed level, part of the explanation dealt with a specific application of the function rule which involves dealing with a fractional input. As Lampert said in her notes for the day, "...I had a big digression on fractions → I decided (off the track?) to throw in '1/4' as an input number, and we needed to do some work on the meaning of 1 3/4 also 7/4 →..." The multiplication of fractions and equivalence of improper and mixed numbers may have been "off the track" but the explanation of the procedure and its justification was not. There was a crispness to the students' public explanation; they were explaining the right thing.

This discussion of explanations started with distinguishing between different kinds of explanations: common, self, disciplinary, and instructional. It was suggested that instructional explanations have a unique aspect because of both style or form and what gets explained. It was also suggested that instructional explanations have properties that are similar to both disciplinary and self explanations. The student is learning from the teacher's explanations not only the content of the explanation, that is, what sorts of things need to be justified, but the manner in which things are explained in terms of ordering and language and structure. A common but not totally universal aspect of an instructional explanation in mathematics is the use to some extent of a representation. This representation generally captures the properties of the entities being discussed (equal fractions) rather than the operations on those entities (cutting the pie); the operations are demonstrated with somewhat less then isomorphic fit (choosing a pie, slicing the pie, demarking without x's all of the pieces, demarking with x's a subset or all of the pieces, counting the pieces, using the total count of demarked -with x- and relating them to the demarked without x is comparable but not identical to adding numerators and retaining denominators). Historical explanations, on the other hand, do not generally use representations. In some classes there is a fairly widespread use of analogies, and quite often a use of examples in supporting an

hypothesis. In the excerpts we used above there was no clear use of analogy or examples; there were, however, voice shifts to help as markers in the explanation.

In both situations the students were learning how to construct their own instructional explanations, explanations which could communicate to their fellow students in the disciplines of mathematics and history, explanations which built up from a shared known language base and were not personally idiosyncratic in ways that destroyed meaning. These explanations were reflections of the students' own powers of reasoning in the respective disciplines. The work that remains is to examine explanations both in a more fine-grained way to establish openings, supports, transitions and conclusions, and in broader ways to see the similarities and differences across subject matter areas.

Why should one study the nature and form of instructional explanations? One reason is that explanations form a core part of all teaching whether or not the style is didactic or dialogue based. Knowing what the aspects of good explanations are, how these aspects are learned, and how to improve on them is important for the education of teachers and for the general improvement of education. As we develop more technologically sophisticated supports for learning we will need increasingly fine-grained understandings of this part of teaching and learning; it is a part that will remain significant. We must avoid letting our technological capability in education outstrip our deep conceptual knowledge of how people and the disciplines they have developed build cohesive, meaningful, memorable explanations for themselves and others.

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List of Figures

Figure 1. Three types of explanations.

Figure 2. Teacher explanation.

Figure 3. Protocol of teacher explanation.

Figure 4. Student explanation.

Figure 5. Protocol of student explanation.

Figure 6. Student and teacher joint explanation.

	WHAT GETS EXPLAINED (PROBLEM)	INITIATION	RULES OF EVIDENCE AND LANGUAGE	COMPLETENESS AND FORM	AUDIENCE
Discipline	Something not yet solved, Reworking in light of disciplinary dialogue	Completion, Reply to challenge	Ritualized, Closed, Formal or Coded, Staccato	All required rules covered, Parsimony, Elegance, Written or spoken	Absent or present members of discipline
Self	Impediment, Contradiction, Cohesive restructuring	Incongruity noticed, Need for cohesion felt, Move from linearity to network	Unrestricted, Experience, Folklore, or Overly narrow & rejecting of intuition	Fragmented, Unique, Enough to satisfy, Personal, Notes, Internal speech	Self
Instructional	Something not understood, Query or elaboration, Plued future knowledge node	Query, Puzzlement, Flagged piece	Discipline, Shared experience, Texts, Resources, Analogies	Understanding or Performance criteria, High redundancy, Speech, Sketchy with respect to formal	Students and teachers

Figure 1. Three types of explanations.

Figure 2. Teacher explanation.

T: Why, I asked Ted, why we need a...

...second Constitution. And he said there were some weaknesses in the original Constitution and that it was impossible to amend, but it was better to write a new document. And I, uh, just would ask you what, what were, uh, these three weaknesses in the Articles that need to be, uh, changed in writing the new laws?. . .

T:...We're talking about national government and strengthening the power...of the central . . .

government. Uh, there were some rather strong weaknesses in the Articles that - the Continental Congress and then of course the government [--] did not have certain, certain powers and most of the national [--] politicians thought, "we'd better do something about this document." And in fact we met at Annapolis and we met, earlier at Mt. Vernon. [And then they] went to Philadelphia. Let's see what Floyd has to say here. What were some weaknesses, Floyd, that you see in the document? The Articles? . . .

Floyd: Congress had only specific powers. Another one was it, there was no power to collect taxes

T: Uh, key point. Now, hear that Marilyn? Okay. They, they can't collect taxes. What else can't they do?

Floyd: Uh, they can't, um. [Well, there's no Federal courts], no judiciary. [--]

T: There's no, no judicial system for the national government . . .

Figure 3. Protocol of teacher explanation.

121 Sovereignty was with the states. I know
122 you have lois of other, uh, uh, points you want
123 to add but I think that gives Marilyn some idea
124 of what we were looking for there. The, the
125 couldn't tax the people directly. It really has
126 no uh . . .

128 .jurisdiction over, uh, interstate commerce.
129 It uh, was ineffective in its conduct here of
130 relationship of state to state. It did not have
131 a national judiciary. But now we're going to
132 Philadelphia, to write a new document.
133 Think we need to take a quick look at, some
134 of the areas of agreement, very quickly. We
135 talked about this the other day. Uh, can you
136 tell me what some of the areas of agreement
137 were of these delegates. So when they sat
138 down and they conversed Pete, and they said,
139 oh sure I agree with you. What kind of
140 government do we want? . . .

144 Everybody, all fifty-five of us who are in
145 the session in Philadelphia are going to say,
146 yes Pete, that's a great idea. That's what we
147 want in government . . .

155 They want a republic. Yes indeed. They
156 want a republic. What else do they want,
157 uh, Tom?

158 Tom: Popular sovereignty?

159 T Where in this document
160 that we're writing in Philadelphia does it say
161 that, the power in this country is with the
162 people? Popular sovereignty. Because
163 everybody at the Convention agrees . . .

190 Tom: I'd say in the Preamble . . .

201 T: The power is with the people. And that's an
202 excellent point for us to what, uh depart if
203 we can from the original question I asked
204 Pete about, the role of agreement. Because
205 when they came to Philadelphia, they did. . .

Figure 3 continued

agree, uh, [on a lot of these] [plans]. They agreed about, uh, who has the power. And they're going to, uh, then begin to uh, uh think about the whole country and realize, [that] this is a major uh, issue where you're getting into concepts - liberty and power in making this Constitution. Therefore Paul if I can ask you to clarify those concepts, would you do that for us?

Paul: Yes. Liberty uh, first of all, has, is not defined only as the absence of compulsion. Which means that it's, liberty is not that strictly defined as somebody infringing [upon our rights]. Liberty is also defined as the opportunity one has to expand. And to live and to grow inside his or her nation. And power on the other hand is not always authority. Power. Au_, authority is, um, we grant somebody, power to do something. Power is having the means to do something. . .

T:In the period, of the revo_, fighting the Revolution from let's say, 1781 to '83. What instrument of government has the power? We'll keep [--] powers in quotes now. In other words, is the controlling agent or, uh, the newly organized states? Who has the power [--]? What agent of government has the power? During the Revolutionary Period? . . .

S: The power was in the states. And the states had the power.

T: Okay. The sovereignty is within the states. Now, if I may go back, to what you were saying about, uh, this power. Since the citizens ha_, are going to get, have the power [inaudible phrase] Constitution, they did not have it during the interim while the Articles were operational. Now, you're saying then that, uh. We're talking about powers act over people, as the agency of government. Liberty would be the, the right.

S: Of the people.

Figure 3 continued

T: Of the people. Power is the authority to act. Now, what does, um, Madison say about, uh, the purpose here of going to Philadelphia and, uh, writing this Constitution, uh, Paul?

S: The purpose for writing the Constitution so to speak, speaking in [--] terms, is to find a happy medium between the two. Because Madison feared if you gave the people too much liberty or freedom, and we discussed this before. One of the biggest fears of the, of people writing at the Convention was that if you gave people too much power and too much say in the government, anarchy could result due to the fact that a lot of people were uninformed...

T: Mm....

S: and things of this nature. By the same token if you gave the government too much power, uh, you would end up getting back to a monarchy or, a, sort of, an aristocracy. . .

whereby a group of rich people or one person, one individual, could control the entire country. And the key to the Constitution was to discover a medium or a balance between these two influ_, or, between these two, uh, contradictory, uh, concepts . . .

T: Remember the question I gave you yesterday and I said, keep it in mind for the next couple of days because we're going to try to determine whether or not the Founding Fathers make a good adjustment, between liberty and power when they write this Constitution . . .

They tended to agree on a number of the important issues . . .

T: What else did they agree upon aside from, uh, the form of the government and uh, uh, the uh, the point here that Pete made. Now that we found all the material, all of you just, can run through it. What else do they agree on?

Figure 3 continued

318 S: Uh, the strength of the centralized
319 government.

320 T: All right those fifty-five men are there
321 because they agree government needs to be,
322 stronger at the national level. What else do
323 they agree upon, uh, Jeff?

324 S: They, they all agree on [--] idea of
325 separation of powers.

Figure 3 continued

Figure 4. Student explanation.

202 Paul:Well another thing is that although
203 Reconstruction fell far short of uh, what
204 the uh, what the radical Republicans
205 originally wanted to do by keeping the
206 radical Republican governments
207 emphasizing strengthening in the South.
208 Uh, I think for the most part the
209 reconstructive period was a necessary
210 period in American history because of the
211 positive things that came up. And we've
212 talked a little bit about uh, the integration
213 of the Blacks into uh, society. And
214 although racial uh, prejudice was not
215 fully overcome, I think we began to move
216 towards that type of trend, the more, ma_,
217 ma_, move toward an equality trend
218 because we had established under the
219 Reconstruction period, things like the
220 Freedmen's Bureau to help uh, the Blacks
221 get along and also to help integrate them
222 in American society eventually. And in
223 addition to this, we also had the basis as
224 Eva said for the system of free education
225 and the building of this system. And in
226 addition to these we also have uh, the
227 voting. Now at the end of the
228 Reconstruction period the thirteenth,
229 fourteenth, and fifteenth amendments
230 which uh, destroy voter qualifications
231 except of course for women, which won't
232 come until 1920. But uh, that is why I
233 would say although it fell far short of the
234 radical Republicans' original intentions as
235 far as keeping the Republican
236 governments in the South, it was quite a
237 constructive period indeed. . .

459 Paul:And I [--] at the beginning of the entire
460 matter, the radicals and the moderates
461 were struggling to push their uh, separate
462 types of Reconstruction through the uh,
463 House. Uh, one of the, one of the biggest
464 things that was there, you'd have to sit

Figure 5. Protocol of student explanation.

down and you'd have to look at how constructive or destructive can a construction period be in terms of the different factions that you have in your country. Because Arnold's right on that point I think you'd all agree that somebody has to come up with some strong, strong leadership. And that's almost for the most part single hand leadership, due to the different factions that you have within a country. First of all you have Blacks coming into the South; you have the angry people who are former Confederates; you have the Blacks that you have to integrate into society and now into politics from the way the radical Reconstructionists were talking. And in addition to this, you also have to deal with the Northern population and their response to the Black movement. Uh, and also you have to deal with the Southerners as far as the Northerners coming in there. There's carpetbaggers and the scouters. There's a lot of dissention, a lot of factions among your country. And uh, the moderates are talking more about implementing a plan whereby we didn't go too harshly with the Southerners when we allowed them to come back to the - with the United States of the Union uh, with only mild consequences and uh, with minor uh,...They wanted to achieve a more or less middle of the road statement where they weren't too radical or they weren't too conservative, to the point of Johnson; or too radical to the point of the radical reconstructionists. However, you, like Arnold said, you need it, you... I think you can sit down and you look at the make-up of the country at that time. Both social and economic uh, you'll find that you needed this type of radical leadership and radical leadership or strong leadership. And what came of it in spite of

Figure 5. continued

the corruption and graft that did result eventually after they had been in power too long, and you had a lot of uh, profiteering, profiteers who were basically looking after their own interests. You basically did have a constructive exercise in our history. Because not on_, what it resulted afterwards you had the beginnings of the uh, integration of Blacks into white society which had to occur sooner or later. Uh_

T: And that's gonna be later. Let's not even, don't even, don't even get that into Reconstruction.

Paul: Yes definitely later. Also, also during Reconstruction you had the issue of Blacks finally getting into politics, not only merely in voting but also uh, into different state conventions to uh, ratify uh, Constitutions and also in uh, other types of legislatures when those governments were trying to be established. Therefore, I would believe in spite of all the destructive things that have gone on with Reconstruction under the radicals, that for the most part it was a construction exercise.

Figure 5 continued

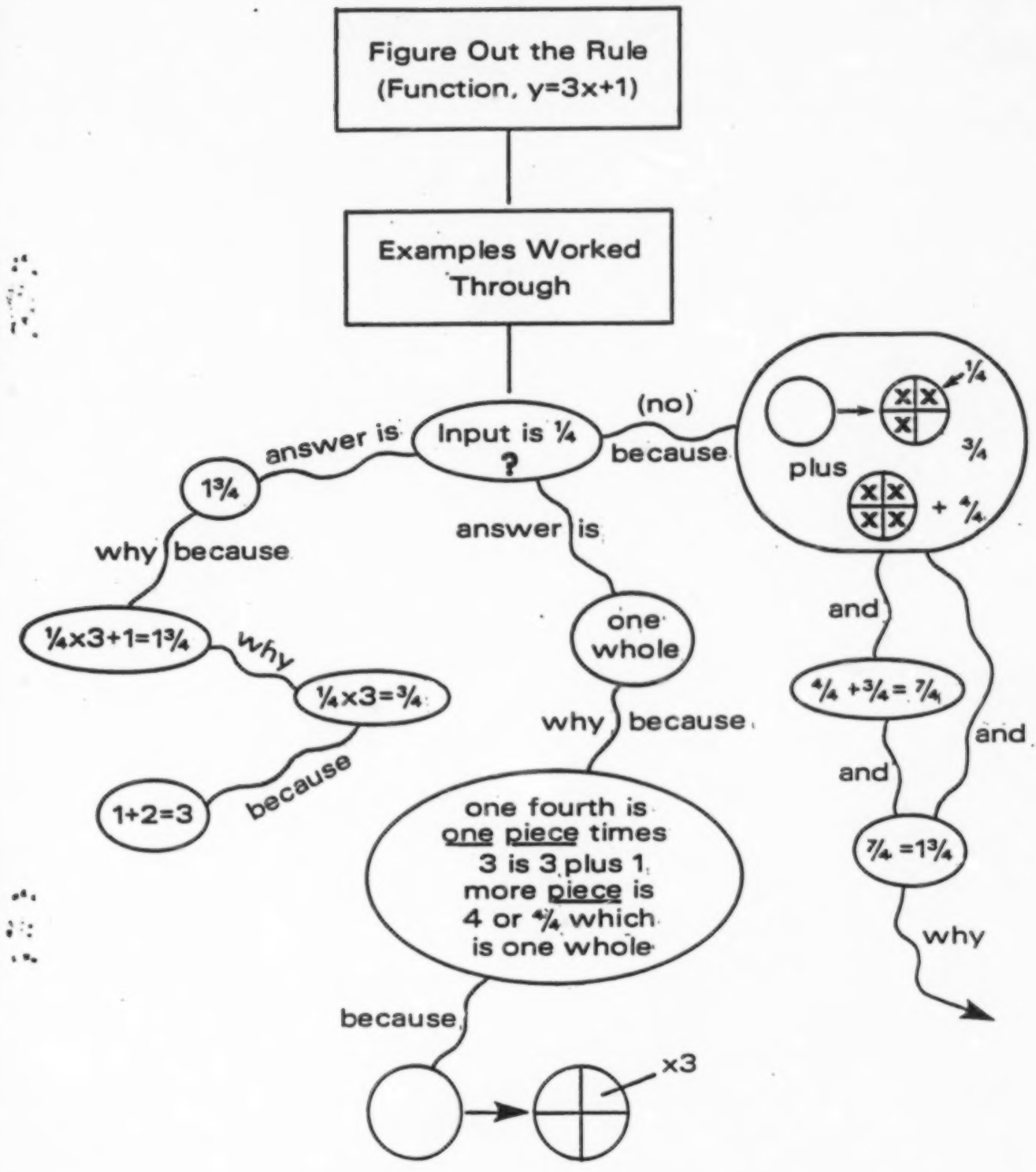

Figure 6. Student and Teacher Joint Explanation
(Lampert, 10/24/88, lines 31-37; 261-372)

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